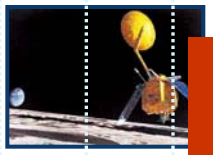
Human System Risk in Exploration and the Human Research Program

Presentation contents:

- Human System Risks in Exploration Missions
  - Pedigree of Human System Risks
  - Nature and Diversity of Human System Risks
- Exploration Risks: How they are baselined and changed
  - Human System Risk Board
  - Relationship to Other Risk Boards

NASA's (Ex-)Exploration Roadmap

05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25



Mars

- Many medical risks (known, unknown, unanticipated)
- Communications difficult (latency delays)
- 30 months mission – no contingency return
- Autonomous medical care absolutely required

Moon (Long duration)

- Many known medical risks, others unknown but anticipated
- Communication
- 2-3 day to access Earth facilities
- Greater autonomy necessary

- 2-3 day to access Earth facilities
- Greater autonomy necessary

Initial Orion Capability

Ares I Development

Commercial Crew/Cargo for ISS

ISS Sustaining Operations

SSP Transition...

NASA's Exploration Roadmap

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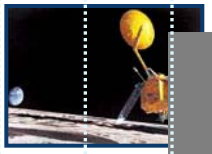


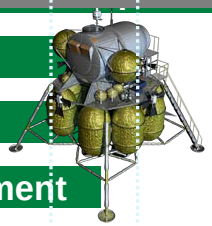
Asteroid

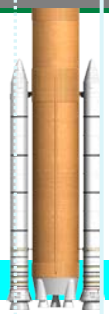
- Many medical risks (known, unknown, unanticipated)
- Crew of 2 (or 3)
- 6 - 12 months mission – contingency return problematic
- Autonomous medical care absolutely required

Lunar Lander Development

Ares V Development

Earth Departure Stage Development





Orion Production and Operations

Orion Development

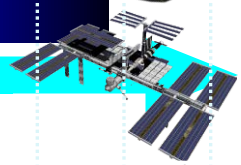
Ares I Development

Initial Orion Capability

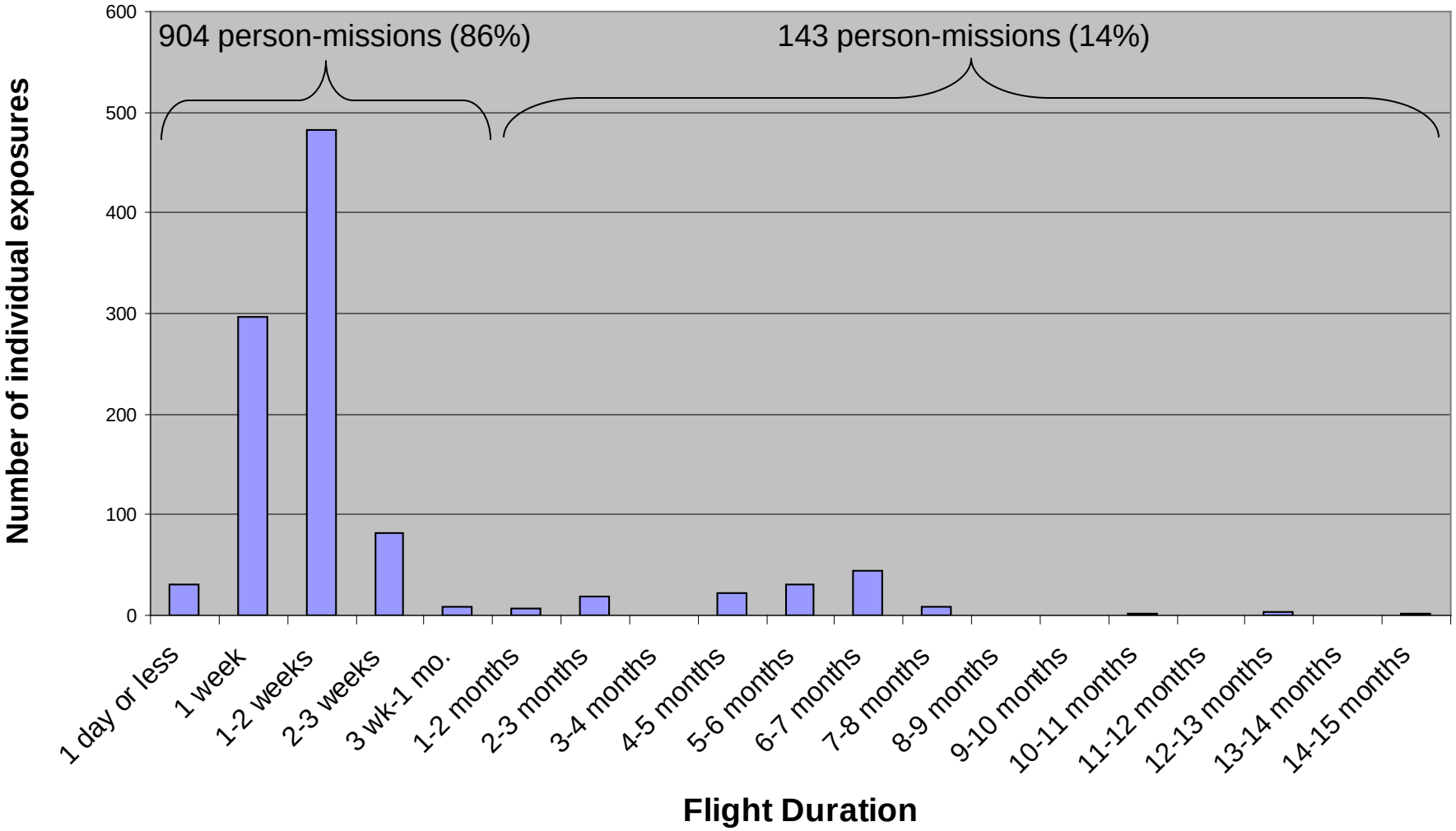
Commercial Crew/Cargo for ISS

ISS Sustaining Operations

SSP Transition...

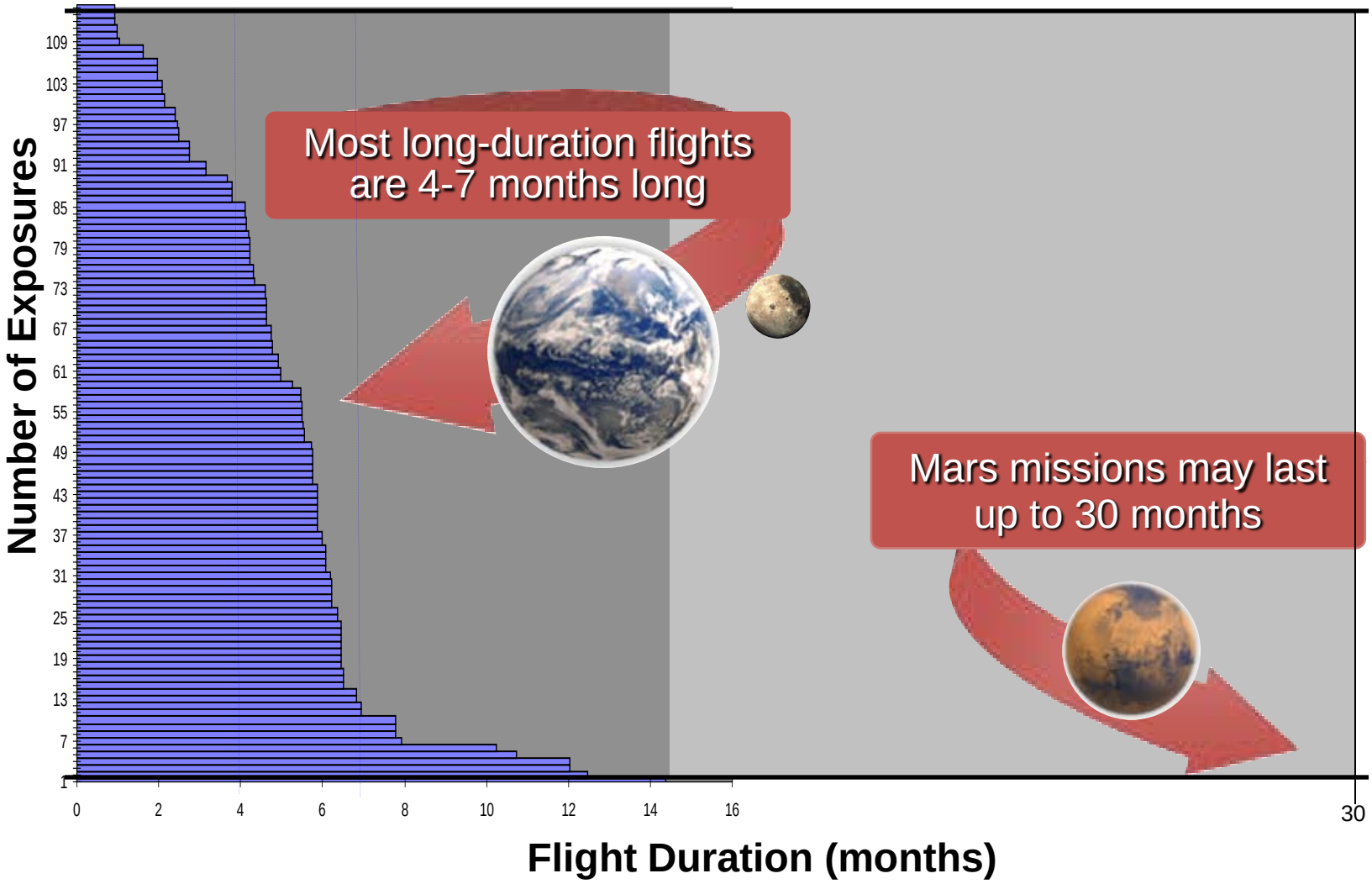


Human Space Flight Experience



Space Flight Experience (continuous)

Flights longer than 28 days



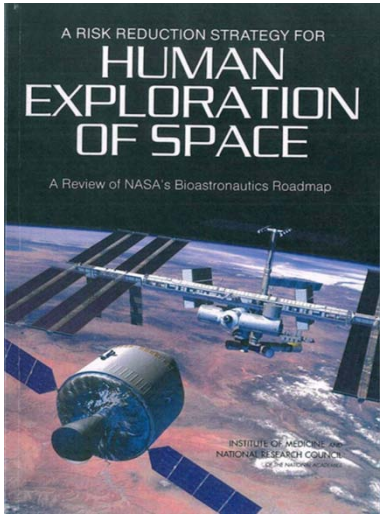
The risks to Human Health and Performance in exploration missions have been developed over 13 years (since 1997).

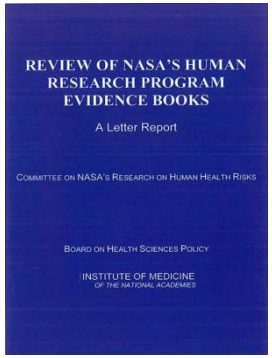
In 2004, NASA published the “Bioastronautics Roadmap” a framework to identify and assess the risks of crew exposure to the hazardous environments of space.

The risks were reviewed by the Institute of Medicine (NRC) with a published report in 2006 – “ A Risk Reduction Strategy for Human Exploration of Space”

In 2008, NASA had updated the risks and mapped them to the missions of space exploration under the Constellation program. NASA published the compiled evidence that supports the risks and requested review by the Institute of Medicine.

In 2008 the IOM published a letter report “ Review of NASA’s Human Research Program Evidence Books”





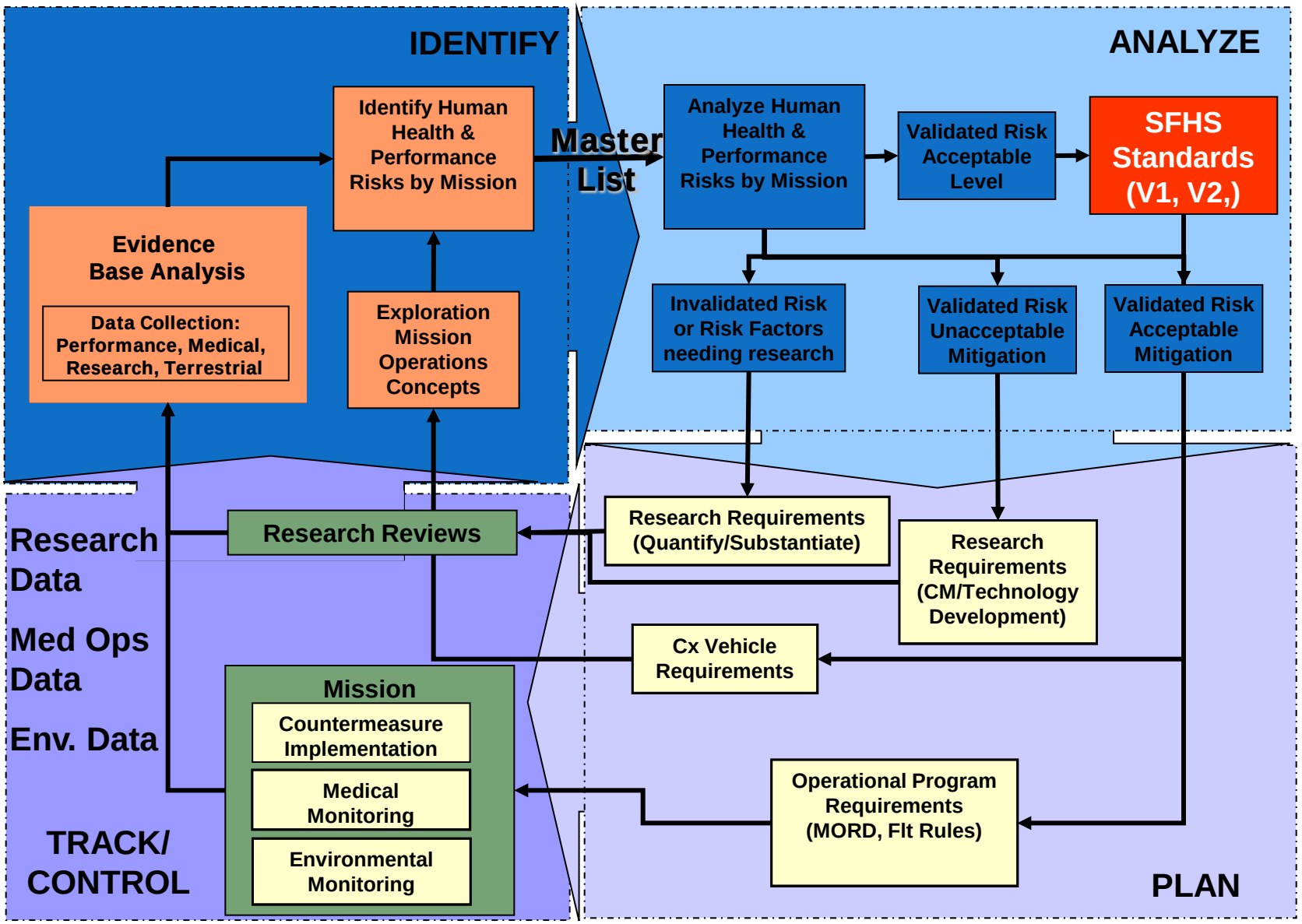
In 2008, NASA established the Human System Risk Board (HSRB) to systematically apply continuous risk management methodology to human system risks for exploration.

HSRB is a multidisciplinary Board with representatives from all aspects of Space Life Sciences/Human Research Program:

- Chief Medical Officer at JSC
- Human Research Program Manager
- Space Medicine
- Human Adaptation & Countermeasures
- Human Factors
- Astronaut representative

As an international adjunct to the HSRB, in 2009, the Collaborative Human System Risk Forum was established to be a venue that will offer all participants the opportunity to hold open discussions concerning the human health and performance risks associated with human space flight. The forum provides a broad-based opportunity for integration to address gaps in knowledge, technology, and other issues.

Overall Human System Risk Management

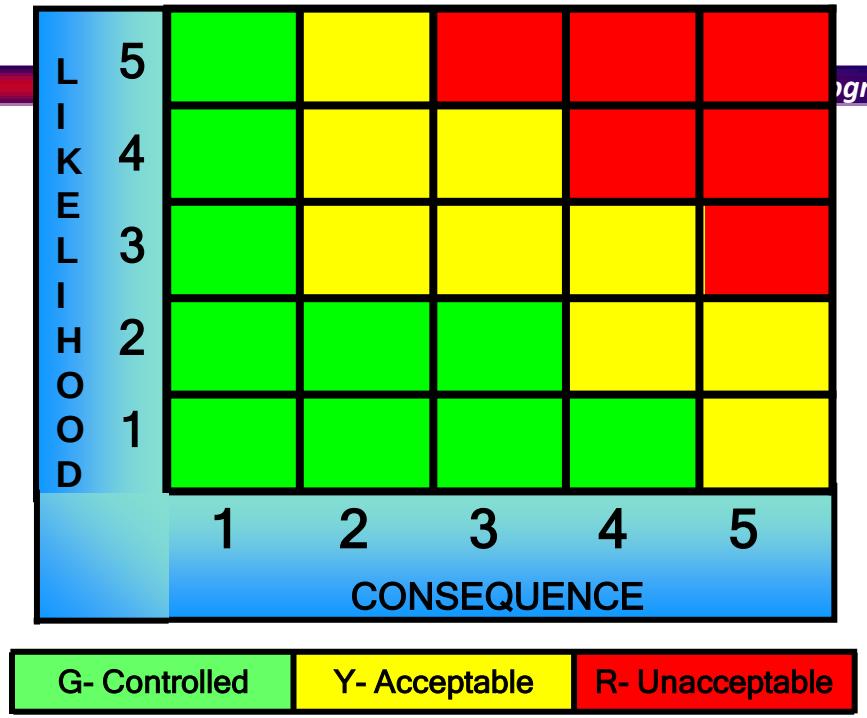


The Human System Risk Board (HSRB) has accepted 42 risks. Of those 42 risks, 28 have been determined to need research either to quantify or substantiate the risks or need countermeasure/technology development to achieve acceptable mitigation. The remainder have adequate operational controls for the missions analyzed.

The risks vary considerably in depth of complexity and analysis. A risk may be described by evidence comparable to terrestrial health risks or may require extensive research data and modeling (such as space radiation , probability of medical events, Decompression Sickness likelihood)

Risk Scorecard

5 -Highly Likely	Nearly certain to occur. Controls have little or no effect. >50%
4 -Likely	Highly likely to occur. Controls have significant uncertainties. 10-50%
3 -Possible	May occur. Controls exist with some uncertainties. 1-10%
2 -Unlikely	Not likely to occur. Controls have minor limitations/uncertainties. 0.1-1.0%
1 -Highly Unlikely	Very unlikely to occur. Strong controls in place. <0.1%



Consequence Criteria				
1	**2**	**3**	**4**	**5**
Very Low	**Low**	**Moderate**	**High**	**Very High**
Physical Health: Injury or illness that is self-limiting **Operational Performance:** Negligible impact to mission operations/objectives **Long Term Health**: Disability is short term	**PH:** Injury or illness requiring treatment **OP:** Minor impact to operations, workarounds available **LTH**: Disability or occupational illness, can be corrected with terrestrial advances in treatment and/or surgery to approximate pre-flight condition	**PH**: Injury, illness, or incapacitation, may affect personal safety or health **OP:** Moderate impact to operations, workarounds available. Potential impact on ability to CoFR. Mitigation possible through operational workarounds **LTH:** Disability or occupational illness, partially corrected, able to compensate	**PH:** Injury, illness, incapacitation or impairment, could be serious enough to lead to evacuation **OP:** Failure to achieve major mission objectives. Significant risk of inability to CoFR, limited mitigation options or operational workarounds **LTH:** Disability or occupational illness, partially corrected, partially compensate	**PH:** Death (LOC) or permanent disabling injury **OP:** Contingency abort (LOM) **LTH:** Permanently disabling injury or illness, unable to correct or compensate; premature death

Status of HRP risks for Exploration Missions

Criticality Metric

- Describes current state of data and information on the risk and its mitigation and countermeasures
  - ✓ Degree of uncertainty in understanding likelihood, consequence, or timeframe
  - ✓ Ability to mitigate risk to an acceptable level
- Criticality metric established for Lunar and Mars missions

U	unacceptable risk that would keep a mission from proceeding
A	acceptable as is, but with a high uncertainty in risk; additional mitigation recommended, and
C	acceptable through use of known controls.

Human System Risks in Exploration Missions –Scoreboard For Risks Requiring Research

Risk	Element	Criticality Lunar	Criticality Mars
Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness, and Work Overload	BHP	C	C
Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team	BHP	C	A
Risk of Adverse Behavioral Conditions and Psychiatric Disorders	BHP	C	U
Risk of Inability to Adequately Recognize or Treat an Ill or Injured Crewmember	ExMC	A	U
Risk Factor of Inadequate Nutrition	HHC	C	U
Risk of Bone Fracture	HHC	C	C
Risk of Intervertebral Disk Damage	HHC	C	A
Risk of Cardiac Rhythm Problems	HHC	C	A
Risk of Renal Stone Formation	HHC	C	C
Risk of Therapeutic Failure Due to Ineffectiveness of Medication	HHC	C	A
Risk of Compromised EVA Crew Health and Performance to Inadequate EVA Suit Systems	HHC	A	A
Risk of Crew Adverse Health Event Due to Altered Response	HHC	C	A
Risk of Orthostatic Intolerance During Re-Exposure to	HHC	C	A
Risk of Impaired Control of Spacecraft, Associated Immediate Vehicle Egress Due to Alterations Associated with Space Flight	HHC	C	A

Human System Risks in Exploration Missions –Scoreboard For Risks Requiring Research

Risk Of Early Onset Osteoporosis Due To Spaceflight	HHC	C	A
Risk of Impaired Performance Due to Reduced Muscle Strength and Endurance	HHC	A	U
Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity	HHC	A	U
Risk of Adverse Health Effects from Lunar Dust Exposure	SHFH	A	n/ a
Risk of Adverse Health Effects Due to Alterations in Host-Microorganism Interactions	SHFH	C	A
Risk of Performance Decrement and Crew Illness Due to Inadequate Food System	SHFH	C	U
Risk of Error Due to Inadequate Information	SHFH	C	A
Risk of Errors Due to Poor Task Design	SHFH	C	A
Risk of Reduced Safety and Efficiency Due to an Designed Vehicle, Environment, Tools or Equipment	SHFH	C	A
Risk of Acute and Late Central Nervous System Effects Radiation Exposure	SR	A	A
Risk of Radiation Carcinogenesis	SR	A	U
Risk of Acute Radiation Syndromes Due to Solar Particle (SPEs)	SR	A	A
Risk Of Degenerative Tissue Or Other Health Effects From Radiation Exposure	SR	A	U

Evidence/Risk-based Management Approach:
Continuous Evaluation of Priorities

Evidence Base – Flight and Ground
- Science
- Clinical
- Operational experience

Reviewed by NRC/IOM

Risks

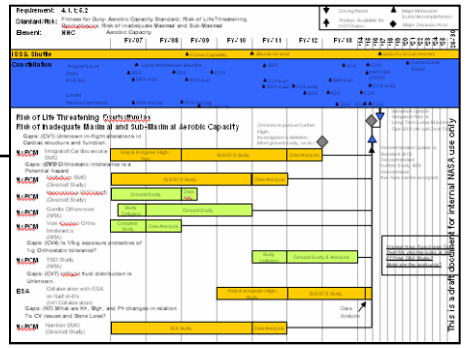
Define Requirements

Perform Gap Analysis

Prioritization & Implementation Approach

Constrained by
- Cx need dates
- Budgets
- Research platform availability

Integrated Research Plan



Define activities

Solicit research

Exploration Missions & Architectures

NASA Spaceflight Human System Standards

Update Evidence Base/Book

Results and Deliverables (>300)
- Retire or Transfer Risks
- Update standards
- Countermeasures
- Medical Technologies
- Results ⇒New Gaps

Evaluate - **ANNUALLY**

Re-evaluating Vision Changes Risk Based on New Evidence

- Original Risk Statement: Given that visual changes have been observed in flight, there is a probability that crew could experience impaired vision during and post flight
- First Presentation given to HSRB on December 9, 2008
  - Tom Mader, M.D.: Spaceflight-induced alterations in intraocular pressure and visual acuity
- HSRB concluded it was a risk that required research and it was to come back to the Board at a later date

Revised Risk on Visual Changes/ICP

The Visual Changes risk was brought back to HSRB twice in 2010, and revised in definition, likelihood and consequence. The risk was elevated to a top risk requiring research.

- Given that all astronauts are exposed to microgravity and cephalad fluid shift, and given that both symptomatic and asymptomatic patients have both exhibited optic nerve sheath edema on MRI, there is a high probability that all astronauts have idiopathic intracranial hypertension to some degree, and that those susceptible (via eye architecture, anatomy, narrow disc) have a high likelihood of developing either choroidal folds or papilledema, and that the degree of that edema will determine long-term or permanent vision loss, sequelae, or impairment.

Human System Risks in Exploration Missions

The frame work of the Risk Management Analysis Tool provides for assessment of the risk and contributing factors for several missions and operational concepts.

Currently (ISS, Lunar Sortie, Lunar Long, and Mars)

The risk assessment for an asteroid mission will fit into this system without difficulty.

Relationship to Other Risk Systems:

The Human Risk System considers other consequences than those typically considered by Spaceflight Programs (such as ISS). Where the risks overlap in Loss of Crew or Loss of Mission (ISS, Constellation), the risk is carried in both systems , cross referenced, and monitored for activity.

ISS Top Program Risk
6169 On-Orbit Intracranial Hypertension
Given that all on-orbit astronauts are exposed to a microgravity-induced cephalad fluid shift.....
Likelihood 4 X Consequences; Cost 3, Schedule 1, Technical 4, Safety 4

Human System Risks in Exploration Missions

- Human system risks for Exploration have been developed systematically, and have been applied to exploration mission reviewed through the IOM.
- The risks are being managed continuously by NASA's Human System Risk Board.
- The Risks and their criticality rating are the basis for establishing the research program content and its priorities.
- The risk framework is enduring and can be adapted to new human exploration missions without problem.